# *On the Observations of Stars made in some British Stone Circles.—Second Note.*

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In a preliminary note communicated to the Royal Society on March 15, 1905, I stated that I was attempting to continue here the researches in temple orientation carried on by myself in Egypt in 1891, by Mr. Penrose in Greece in 1892, and by both of us at Stonehenge in 1901.

I pointed out that from the observations I had made at the Hurlers and Stanton Drew, of which I gave an account, it seemed probable that the outstanding stones of our ancient monuments had been erected to assist astronomical observations.

Since the date of the preliminary note I have, in intervals of leisure, visited many of the British monuments, and friends have been good enough to make observations at others. I propose in the present note to state as briefly as possible the chief results I have obtained in cases where the enquiry has been complete enough to warrant definite conclusions being drawn. I have not in all cases been able to make a complete survey of the azimuths and the height of the sky-line of the existing monuments, and everywhere the destruction has been so serious that a complete story in any locality is out of the question.

## *Clock-Stars.*

The practice so long employed in Egypt of determining time at night by the revolution of a star round the pole was followed in the British Circles.

This practice was to watch a first magnitude star, which I named a "clock-star," * of such a declination that it just dipped below the northern horizon so as to be visible for almost the whole of its path.

One of the earliest temples in Egypt concerning which we have historical references to check the orientation results, was built to carry on these night observations at Denderah, lat. N. 26° 10′. The star observed was $\alpha$ Ursæ Majoris, decl. N. 58° 52′, passing 5° below the northern horizon; date (for horizon 1° high) about 4950 B.C., *i.e.*, in the times of the Shemsu Heru, before Mena, as is distinctly stated in the inscriptions.

After $\alpha$ Ursæ Majoris had become circumpolar in the latitude of Denderah, $\gamma$ Draconis, which had ceased to be circumpolar, and so fulfilled the conditions to which I have referred, replaced it. Its declination was 58° 52′ N. about

* 'Dawn of Astronomy,' 1894, p. 343.

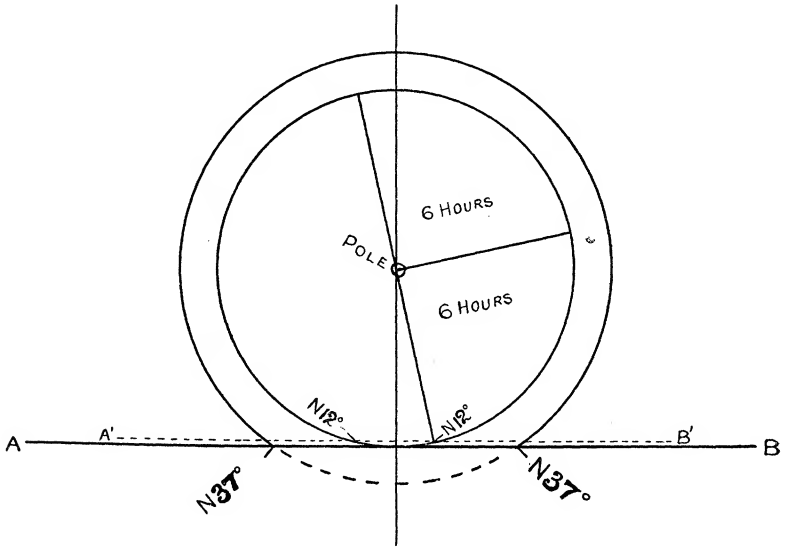
3100 B.C., and it therefore could have been watched rising in the axis prolonged of the old temple in the time of Pepi, who restored it then, and is stated to have deposited a copy of the old plan in a cavity in the new walls.

So far as the enquiry has gone, these clock-star observations were introduced into Britain about 2300 B.C. In my statement concerning them I will deal with the astronomical conditions for lat. 50° N., as it is in Cornwall that the evidence is most plentiful and conclusive.

In that latitude and at that time Arcturus, decl. N. 42°, was just circumpolar and therefore, with a sea horizon, neither rose nor set. Capella, decl. N. 31°, when northing, was 9° below the horizon, so that it rose and set in azimuths N. 37° E. and N. 37° W. respectively; it was therefore invisible for a long time and was an awkward clock-star in consequence.

Fig. 1 represents diagrammatically the conditions named, the circumpolar paths of Arcturus and Capella being shown by the smaller and the larger circle respectively. AB represents the actual sea horizon and A′B′ a locally raised horizon, whilst the dotted portion of the larger circle represents the non-visible part of Capella's apparent path.

FIG. 1.




What the British astronomer-priests did therefore in the majority of cases was to set up their temples in a locality where the N.E. horizon was high, so that Arcturus rose over it and was invisible for only a short time, as shown in the diagram by the raised horizon A′B′.

The two following lists contain the names and positions of monuments where Arcturus was used as a clock-star. In the first, the elevation of the

sky-line in each case has been actually measured, and the meaning and date of the alignment are therefore fairly trustworthy; but in the second list the elevations have been estimated from the differences of contour shown on the 1-inch Ordnance map, and the dates must be accepted as open to future revision.

## Arcturus as a Clock-Star.

i.

| Monument. | Position. | | Alignment. | Az. | Hills. | Decl. N. | Date B.C. |
|---|---|---|---|---|---|---|---|
| | Lat. N. | Long. W. | | | | | |
| Tregeseal ..... | 50° 7′ 50″ | 5° 39′ 20″ | Circ. to Carn Kenidjack | N. 12° 8′ E. | 4° 0′ | 42° 33′ | 2330 |
| | | | Circ. to barrow 800′ dist. | N. 20 8 E. | 3 50 | 40 29 | 1970 |
| The Hurlers*... | 50 31 0 | 4 27 20 | S. circ. over cent. circle | N. 11 15 E. | 3 24 | 41 38 | 2170 |
| | | | Cent. circ. over N. circle | N. 14 18 E. | 3 24 | 41 9 | 2090 |
| | | | N. circ. over N.E. barrow | N. 18 44 E. | 3 24 | 40 6 | 1900 |
| Merrivale ..... | 50 33 15 | 4 2 30 | Direction of smaller avenue | N. 24 25 E. | 5 0 | 39 55 | 1860 |
| Fernworthy ... | 50 38 30 | 3 54 10 | Direction of avenue | N. 13 0 E. | 1 15 | 39 7 | 1720 |
| | | | Second direction of avenue | N. 14 20 E. | 1 15 | 38 51 | 1670 |
| Stanton Drew... | 51 22 0 | 2 34 30 | Cent. of Gt. Circle to Quoit | N. 17 59 E. | 2 33 | 38 38 | 1620 |
| Fernworthy ... | 50 38 30 | 3 54 10 | Direction of avenue | N. 15 45 E. | 1 15 | 38 34 | 1610 |
| Merry Maidens | 50 3 40 | 5 35 25 | Circ. to stone in the road | N. 11 45 E. | 0 12 | 38 27 | 1590 |
| Stanton Drew... | 51 22 0 | 2 34 30 | S.W. circ. to cent. of Gt. Circ. | N. 19 51 E. | 1 44 | 37 30 | 1420 |

* The dates here given for the Hurlers are earlier than those stated in the preliminary paper with an assumed sky-line. The actual elevation of the horizon has, in the meantime, been supplied by Captain Henderson. The alteration of the Stanton Drew date is not so great because the hills are lower.

ii.

| Monument. | Position. | | Alignment. | Az. | Hills. | Decl. N. | Date B.C. |
|---|---|---|---|---|---|---|---|
| | Lat. N. | Long. W. | | | | | |
| Trowlesworthy ... | 50° 27′ 30″ | 4° 0′ 20″ | Direction of primary avenue | N. 7° 0′ E. | 2° 52′ | 41° 24′ | 2130 |
| | | | Direction of final avenue | N. 12 0 E. | 2 52 | 41 6 | 2080 |
| Longstone (Tregeseal) | 50 8 10 | 5 38 10 | Longstone to Chûn Cromlech | N. 9 0 E. | 1 43 | 40 39 | 2000 |
| Lee Moor ..... | 50 26 30 | 3 59 40 | Direction of avenue | N. 22 0 E. | 2 28 | 38 17 | 1560 |

In some cases, for one reason or another, this arrangement was not carried out, and Capella, in spite of the objection I have stated, was used in the following circles :—

Capella as a Clock-Star.

| Monument. | Position. | | Alignment. | Az. | Hills. | Decl. N. | Date B.C. |
|---|---|---|---|---|---|---|---|
| | Lat. N. | Long. W. | | | | | |
| i. | | | | | | | |
| Boscawen-Un ... | 50 5 20 | 5 37 0 | Circ. to Stone Cross | N. 43 15 E. | 2 7 | 29 26 | 2250 |
| Merry Maidens... | 50 3 40 | 5 35 25 | Circ. over "The Pipers" | N. 38 26 E. | 0 20 | 29 58 | 2160 |
| ii. | | | | | | | |
| The Nine Maidens | 50 28 20 | 4 54 30 | Direction of Nine Maidens row | N. 28 0 E. | 0 0 | 33 47 | 1480 |
| Stripple Stones... | 50 32 51 | 4 37 5 | Centre to N.E. bastion | N. 26 0 E. | 0 22 | 34 38 | 1320 |

At the Merry Maidens, however, with nearly a sea-horizon, when Arcturus ceased to be circumpolar, and rose and set in azimuth N. 11° 45′ E., it replaced Capella and was used as a clock-star after 1600 B.C.

*The May-Year.*

The first astronomical immigrants into Britain brought the May-year with them. This year is quartered by the sun's passage four times through 16° 20′ decl. N. and S., the Gregorian dates being May 6, August 8, November 8, and February 4.

There is evidence that this year was used in Babylon, Egypt, and afterwards in Greece. In the two former countries May was the harvest month, and thus became the chief month in the year. The dates were apt to vary slightly with the local harvest time. The earliest temple aligned to the sun at this festival seems to have been that of Ptah at Memphis, 5200 B.C. This date of the building of the temple is obtained by the evidence that the god Ptah represented the star Capella, as there is a Ptah temple at Thebes aligned on Capella and outside the solar limit.

There was also, in all probability, a similar temple at Annu (Heliopolis, lat. N. 30° 10′), but it has disappeared. The light of the sun fell along the axis when the sun had the decl. N. 11°, the Gregorian dates being April 18 and August 24.

Another May temple is that of Menu at Thebes (lat. N. 25°), date 3200 B.C., sun's decl. N. 15°, Gregorian date, May 1.

The researches of Mr. Penrose in Greece have provided us with temples

oriented to the May-year sun at Athens (including the Hecatompedon and older Erechtheum), Corinth, and Ægina.

The explorations of Sir H. Layard at Nineveh have shown that the temple in Sennacherib's palace was also oriented to the May sun.

Alignments in British monuments designed to mark the place of the sun's rising or setting on the quarter-days of the May-year have been found as follows:—

| Monument. | Position. | | May and August. | | February and November. | |
|---|---|---|---|---|---|---|
| | Lat. N. | Long. W. | Rising. | Setting. | Rising. | Setting. |
| | ° ′ ″ | ° ′ ″ | | | | |
| Merry Maidens ..... | 50 3 40 | 5 35 25 | × | × | | × |
| Boscawen-Un ..... | 50 5 20 | 5 37 0 | × | | × | ? |
| Tregeseal ..... | 50 7 50 | 5 39 20 | × | | ? | |
| Longstone (Tregeseal) | 50 8 10 | 5 38 10 | × | | | ? |
| Down Tor..... | 50 30 10 | 3 59 30 | × | | | |
| Merrivale ..... | 50 33 15 | 4 2 30 | × | | | |
| The Hurlers..... | 50 31 0 | 4 27 20 | | | × | ? |
| Stonehenge ..... | 51 10 40 | 1 49 30 | × | × | | |
| Stanton Drew ..... | 51 22 0 | 2 34 30 | × | | | |
| Stenness ..... | 59 0 10 | 3 13 40 | × | × | × | × |

It was the practice in ancient times for the astronomer-priests not only to watch the clock-stars during the night, but also other stars which rose or set about an hour before the sun so as to give warning of its approach on the days of the principal festivals.

Each clock-star, if it rose and set very near the north point, might be depended upon to herald the sunrise on *one* of the critical days of the year, but for the others other stars would require to be observed.

That this practice was fully employed in Britain is shown below:—

May Warnings.

| Monument. | Star. | Date, or dates, B.C. |
|---|---|---|
| Stonehenge ..... | Pleiades (R) | 1950 |
| Merry Maidens ..... | Pleiades (R) | 1930 |
| | Antares (S) | 1310 |
| The Hurlers ..... | Antares (S) | 1720 |
| | Pleiades (R) | 1610 |
| Merrivale ..... | Pleiades (R) | 1610 |
| | | 1420 |
| Boscawen-Un ..... | Pleiades (R) | 1480 |
| Tregeseal ..... | Pleiades (R) | 1270 |
| Stenness ..... | Pleiades (R) | 1230 |
| Longstone (Tregeseal) ... | Pleiades (R) | 1030 |

(R) = rising. (S) = setting.

*August Warnings.*—Sunrise at the August festival was heralded by the rising of Arcturus which, as we have seen, was also used as a clock-star.

The alignments and dates given in the Arcturus table therefrom hold good for August. At the Hurlers, where the hill over which Arcturus was observed fell away abruptly, we find Sirius supplanting Arcturus as the warning star for August in 1690 B.C.

*November Warnings.*—So far I have discovered no evidence that any star was employed to herald the November sun. There are two obvious reasons for this :—

In the first place, at the November festival the celebration took place at sun*set*, and the sun itself could be watched.

Secondly, the prevalent atmospheric conditions which obtain in Britain during November would not be conducive to the making of stellar observations *at the horizon ;* and the people who built these temples only observed risings or settings.

*February Warnings.*—In just the same way that Arcturus served the double purpose of clock-star and herald for the August sun, so did Capella serve to warn the February sun in addition to its use as a clock-star. The alignments and dates given in the Capella table, will, therefore, hold good for its employment at the February quarter-day.

### *The Solstitial Year.*

I have evidence that the observation and worship of the solstitial sun, such as was carried on in Egypt, at Karnak and possibly places of still greater antiquity,* was continued in other stone temples in Britain besides Stonehenge.

Although some of the alignments already found are in all probability solstitial, the variation of the sun's solstitial declination is so small that the most careful determination of their azimuths and angular elevations of the horizons must be made before the declinations and consequent dates can be arrived at.

Such a determination was made by Mr. Penrose and myself at Stonehenge in 1901 and reference to our paper† on the subject will show that, even after taking the greatest precautions, we were unable to fix the date of the monument with a smaller limit of error than 200 years.

Those monuments at which possible solstitial alignments have so far been found are given in the following table :—

* 'Dawn of Astronomy,' p. 78, London, 1894.

† 'Roy. Soc. Proc.,' vol. 69, pp. 137—147.

| Monument. | Summer solstice. | | Winter solstice. | |
|---|---|---|---|---|
| | Rising. | Setting. | Rising. | Setting. |
| Stonehenge | × | | | |
| Stanton Drew | × | | | |
| Stenness | × | | × | × |
| Boscawen-Un | × | | | |
| Tregeseal | × | | | |
| Longstone (Tregeseal) | | | | × |

In several instances, as for example at the Boscawen-Un circle, there are two stones near to the solstitial sight-line, one of which can never have been used to indicate the solstitial line. Nearly the same thing occurs at Stonehenge where the isolated monolith, the Friar's Heel, is near, but to the east of the solstitial sight-line (*i.e.*, the avenue).

It seems probable that the solstice festival being of fundamental importance with the temple builders, they needed some *days* of warning instead of the hour or so provided by an heliacal rising or setting of a star. For this reason the stone was erected so that sunrise would take place in its direction some days before the solstice. In all the cases yet noted this stone is on the equator side, *i.e.*, to the E. of the true solstitial line and so would act as a warner.

*The Equinoctial Year.*

Only in one or two of the temples yet investigated has any evidence of an equinoctial worship been discovered. Even in these cases it is not conclusive, so for the present I leave this part of the question open.

My best thanks for assistance in the present enquiry are due to the following:—

To Colonel Duncan A. Johnston, R.E., C.B., late Director-General of the Ordnance Survey, and to Colonel R. C. Hellard, R.E., the present Director-General, I am indebted for the azimuths of the side-lines on various 25-inch maps and of several important sight-lines.

Mr. W. E. Rolston, F.R.A.S., one of the computers in this observatory, has calculated the declinations of the sun and stars corresponding to the azimuths determined, the consequent dates being taken from the tables prepared by Mr. J. N. Stockwell, Dr. W. J. S. Lockyer and Dr. O. Danckwortt.

In obtaining local particulars and measurements I have received invaluable assistance from Captain J. S. Henderson and Mr. Horton Bolitho

at the Hurlers, Professors Lloyd Morgan and Morrow and Mr. Dymond at Stanton Drew, and Messrs. H. Bolitho, H. Thomas and Captain Henderson in south-west Cornwall.

To Lord Falmouth and Mr. Wallis I am also under obligations, as they were good enough to assist my inquiries by allowing an opening to be made in a stone wall at the Merry Maidens to view the alignment to the Pipers.

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# *On the Distribution of Radium in the Earth's Crust, and on the Earth's Internal Heat.*

By the Hon. R. J. Strutt, F.R.S., Fellow of Trinity College, Cambridge.

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## § 1.—*Introduction.*

Professor Rutherford* has given a calculation which suggests that there may be enough radium in the earth to account for the temperature gradient observed near the surface.

The question is of great interest from a cosmical point of view. For if we find that the earth's internal heat is due to radio-activity, and if we assume, as has been usual, that this heat is due to some vestiges of the cause operative in the sun and stars, it would follow that these latter are heated by radio-active changes also.

Professor Rutherford's calculation was based on some data given by Elster and Geitel on the amount of radium emanation which diffused out from a sample of clay. These data were obtained at a time when the quantitative determination of minute amounts of radium was not well understood, and are moreover inadequate to give any general idea of the average amount

* 'Radio-activity,' p. 494, 2nd Edition.